Go to contents 03

Modelling of User Activities in Building Design

EKHOLM, Anders
Professor of Architectural and Building Design Methodology, School of Architecture, Lund Institute of Technology, Lund University
http://www.caad.lth.se/ Anders.Ekholm@caad.lth.se

Architects manage not only information about the building but also about the user organisation. Therefore, information systems for architectural design must be able to handle both building and organisational data. The paper describes architectural design as a creative problem solving process, and presents a recently developed prototype application for user activity modelling built as an add-on to ArchiCAD.
Keywords: *Architectural design, problem solving, user activity modelling, model based CAD*

Introduction

Revolutions in architectural design practise

During the last 10-15 years the personal computer together with different software for visualisation, calculation and simulation have revolutionised architectural design practise. For most tasks the drawing-table has been abandoned in favour of the computer platform. Currently, a second revolution takes place where building CAD programs are shifting focus from drawing to modelling.

The shift from drawing to modelling means that the design, i.e. the conceptual model of the designed object, is represented externally, outside the mind of the designer. This requires that both the process of design and the objects of design must be problemized: What is design, and what is designed?

The general idea is that model oriented CAD-programs enable the designer to develop an object based "product" model of the building. Building product models enable computer integrated construction and facility management processes, CIC/FM, (Björk 1995). It also enables new ways of managing and structuring design information (Eastman 1999).

However, building design is a complex process involving knowledge not only of the building or the built environment but also the user organisation activities (Ekholm 1987). The building design process starts with describing the user organization and its requirements on the building, then, gradually the focus is shifted towards the building, its construction and maintenance.

The design process is a process of search and gradual development (Simon 1981). It is less a matter of choice among ready-made alternatives than a matter of creative problem solving. A requirement on computer support for design is that both functional requirements and technical solutions can be creatively combined.

The use of model based design and information management systems in the early stages during the programming and proposal stages, as well as in the facility management stages, put new requirements on CAD systems. This paper reports results from the development of a prototype program for user activity modelling. It also reflects on how user activity modelling fits into the building design process.

This research has applied a generic conceptual framework based on Mario Bunge's Treatise on Basic Philosophy (Bunge 1977, 1979,1983 and 1985). The concepts used in this paper have been presented in earlier writings by the author, the interested reader is recommended e.g. (Ekholm 1987, 1994 and 2001, and Ekholm and Fridqvist 1996, 1998 and 2000).

A conceptual framework for building design

Design as creative problem solving

The development of architectural design systems must be based on knowledge of the architectural design process. Before discussing the subject of architectural design some general aspects of design are necessary to clarify. The verb design means “to conceive and plan out in the mind”, and the noun design means “a mental project or scheme in which means to an end are laid out” (Webster’s 1999). Accordingly, a design (verb) process results in a design (noun).

Design may be seen as a problem solving process similar to problem solving in everyday life or in science. In general, “a problem arises when a living creature has a goal and does not know how this goal is to be reached” (Duncker 1945). A problem can be defined as lack of knowledge about a thing or process, in relation to some background knowledge (Bunge 1983:271). Problem solving in general is a process of purposeful exploration (ibid:234). The specific character of a design problem is to define a satisfactory state of a thing or process and devise a cause of action that results in this state.

A problem solution, also called hypothesis, describes the object or its state in a way that is satisfactory, and eventually enables a test. The test may be theoretical, relating the solution to existing knowledge, or empirical, involving an experiment or construction and test of an artefact. During a design process, hypotheses and tests are made alternately and properties of the intended artefact are determined in an incrementally.

Simon (1981) has envisioned a unified science of design as a possible research objective, while Bunge (1985:227) has questioned this on the grounds that “every design problem calls for specialized knowledge as well as creative imagination”. The knowledge needed in different fields of design is so diverse, e.g. concerning functions and materials, that it is impossible to learn to design apart from the artefacts to be designed. However, following Bunge there are generic theories of artefacts and of intellectual work that could be applied in every design field. The following sections outline some generic aspects of the substantive and methodological knowledge that is relevant for architects as well as other designers.

Systems and properties

A basic concept in a description of the concrete world is that of system. A system is a complex thing with bonding relations among its parts, it has composition, environment and structure, both intrinsic and extrinsic. A process is a sequence of events in a system; an activity is a goal-directed process. The terms ‘process’ or ‘activity’ may also be used to designate the system itself since it is a characteristic feature. An artefact is a man-made or man-controlled system; it is made with a purpose to make certain activities possible. A human activity system that involves the use of artefacts is also called a sociotechnical system. Work is a specific kind of activity, it is a useful activity. A sociotechnical system engaged in some work activity is in management science called an ”organisation” (Child 1984), ”human activity system” (Checkland 1981), or ”enterprise” (Bubenko 1993).

To adopt a view, or aspect, on a system is to observe a specific set of properties. Of specific interest to design are the functional and compositional views. A functional view focuses on the system’s extrinsic properties, its relations to the environment, while a compositional view focuses on intrinsic properties, i.e. the compositional parts from which it is assembled. See Figure 1.

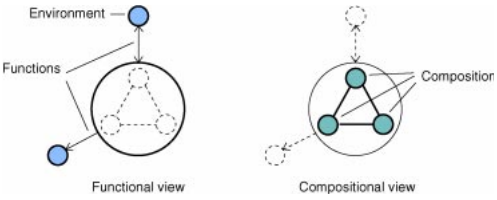

Figure 1. Functional and compositional views on systems

The problem solving cycle

Every design process is initiated by a problem. The problem definition is followed first by synthesis, leading to a tentative solution, and then by analysis, investigating the proposed solution. The synthesis question is: Which object has these properties? And the analysis question is the inverse: Which properties does this object have? Synthesis may be regarded as proceeding top-down, from a functional view on the object, while analysis proceeds bottom-up, from a compositional view. The result of analysis is added to the background knowledge. The design cycle, by Simon (1981:149) called the Generator-Test Cycle, proceeds until a satisfactory solution has been developed. The cycle is illustrated below in Figure 2.

A design problem may be characterised as open or closed, and the process of problem solving routine or innovative. To a closed problem the determining factors and their combinations are well known; it may be solved by a routine that consists in selecting a prototype solution and determining the values of its attributes. To an open problem, neither the determining factors nor their combinations are known. A prototype solution cannot be applied since new kinds of things or processes must be explored or invented. Open problems have been called called ”wicked” (Rittel 1984).

User activity information in architectural design

When an organisation is formed or changed, it may require a new or renewed building. The process of acquiring a suitable building starts with a description of the organisation and its activities. The activity description is used as a basis for developing a space function program which defines requirements on the building’s spaces. The following step includes development of a building program which defines additional requirements on the building. The building program together with the activity description and the space program are used as a background for building design, but can also be used for building performance analysis during the facility management stage. See Figure 2.

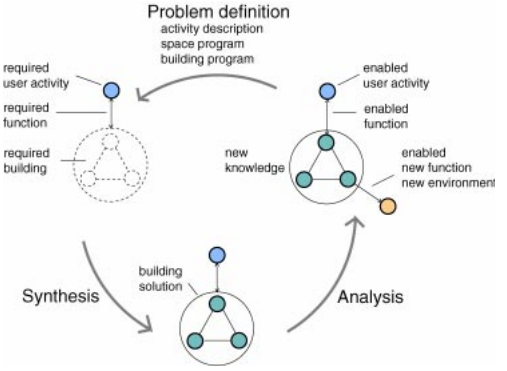

Figure 2. The building design process

Model based CAD-systems for building design may support the fundamental design steps of problem definition, synthesis and analysis. An application that allows the development of a user activity description assists the problem definition work, while the building design application assists the synthesis work and allows the designer to document the building property decisions. Building analysis includes technical performance analysis, cost calculations as well as usability analysis. Spatial performance may be analysed visually, but certain analyses would be possible to automate, e.g. fire escape routes, ventilation, and lighting levels. The test results are used as background knowledge for subsequent design process cycles

Information systems for building design

Static and dynamic information systems

An information system is a computer based system which makes it possible to store and retrieve information of relevance to the information needs of a user. It consists of a conceptual schema, an information base and an information processor (ISO 1985:15). The conceptual schema is a generic conceptual representation of the objects that the system handles information about, it is made up of

entities, attributes and relations between entities. The information base holds the attribute values. The information processor is a software tool that makes it possible to query and update the conceptual schema and the information base.

Information systems can be characterised as dynamic or static concerning the possibility for the user to define new attributes in the conceptual schema, and to classify model objects. These two characteristics are mutually independent. In a static system, the model objects have to retain their classification once instantiated into the model. In a dynamic system the user can reclassify model objects during modelling. The user cannot create new classes or attributes in a static system, which is possible in the dynamic system.

A model based CAD-system based on a fixed classification schema is not suitable for use in the earliest, most dynamic phases of design, since the fixed schema is at odds with the evolving semantics of design (Eastman and Siabiris 1995).The BAS•CAAD system developed by Ekholm and Fridqvist (1998) and also presented in (Fridqvist 2000) is an example of a fully dynamic system, while the Activity add-on presented in the following sections is static concerning definition of new attributes, but to some extent dynamic concerning reclassification of model objects.

The Activity add-on prototype

The ideas of user activity modelling from the BAS•CAAD project were implemented in the Activity add-on project. An add-on is a separate program that expands the functionality of a another program, and can only be run within this. The Activity add-on was developed for the established architectural design software ArchiCAD. It has its own user interface accessible from the interface of ArchiCAD, e.g. new menus, dialogue boxes, floating palettes, etc.

The basic entity of the Activity add-on is the Activity. It is based on a functional view on an organisation or part of an organisation. An Activity may have other activities as functional parts or itself be a functional part of other activities. Activities are composed of Person and Equipment. The constituent Person and Equipment may be determined for an Activity at any level in the “hierarchy”. Activities may have Name, Description, Duration, and Relations. There are four Relations that can be specifically shown: Visibility, Sound, Distance, and Adjacency. These may have values which, however, can only be described, functionality is not implemented. A Person can only exist within an Activity. Equipment may be composed of other Equipment, and can exist independently during the time period between the Activities in which it appear. Figure 3 shows an example of the user interface.

Further investigations

The Activity add-on was tested by modelling a small school and its classes during a day, a comprehensive presentation is made in (Ekholm 2001). Activity modelling applications may strongly enhance the functionality of building design software, especially in the problem definition and analysis phases of design. The integration of activity objects in software for building design opens new possibilities for building design methods development.

In this prototype it has not been possible to implement a relation between activities and building spaces, or functions to manage all the information needed for space function programming. Several aspects could be investigated in further implementations, for example:

- Illustration of user activities and how they are accommodated in the building
- Spatial lay-out which coordinates spatial requirements of buildings and activities
- Temporal space use analysis for different use during a time period
- Versatility analysis of the building’s capacity to accommodate different activities
- Space function programs for building design and facility management

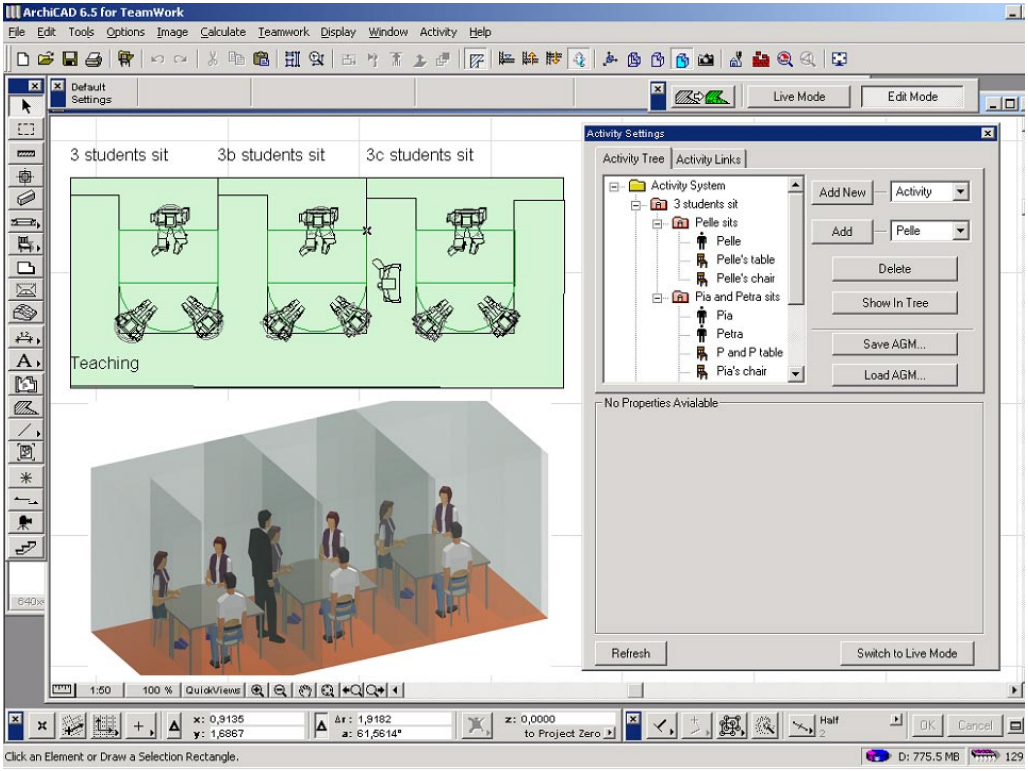

Fig 3: User interface from the Activity Add-on

- Libraries of activity systems together with their building requirements
- Process modelling representing input and output of processes.

References

Björk B.-C. 1995. Requirements and information structures for building product data models. VTT Publications 245 (Technical research centre of Finland, Espoo)

Eastman C. 1999. Building Product Models: Computer Environments Supporting Design and Construction. CRC Pr, London.

Bubenko jr J. A., 1993, ”Extending the scope of information modelling”, Report No. DSV 93-034. Department of Computer and Systems Science, KTH, Stockholm.

Bunge M. 1977. Ontology I: The Furniture of the World, Vol. 3 of Treatise on Basic Philosophy. Reidel, Dordrecht and Boston.

Bunge M. 1979. Ontology II: A World of Systems, Vol. 4 of Treatise on Basic Philosophy. Reidel, Dordrecht and Boston.

Bunge M. 1983. Epistemology and Methodology I: Exploring the World, Vol. 5 of Treatise on Basic Philosophy. Reidel, Dordrecht and Boston.

Bunge M. 1985. Epistemology and Methodology III: Philosophy of Science and Technology, Vol. 7 of Treatise on Basic Philosophy. Reidel, Dordrecht and Boston.

Checkland P. 1981. Systems Thinking, Systems Practice. John Wiley & Sons, Chichester.

Child J. 1984. Organization: A guide to problems and practice. Paul Chapman Publ. London.

Duncker K. 1945, On problem-solving Psychological Monograph 58, No. 270. Quoted from (Bunge 1983:235).

Eastman C. M. and A. Siabiris 1995. “A generic building product model incorporating building type information”. Automation in Construction, 3(4), p. 283-304.

Ekholm A. 2001. “Activity objects in CAD programs for building design”. Forthcoming in Proceedings from CAADFutures 2001. TUE, Eindhoven.

Ekholm A., 1994, “A systemic approach to building modelling – analysis of some object-oriented building product models”. In: Björk, B.-C. (ed.) CIB W78 Workshop, Aug. 22-24 1994, Esbo, Finland.

Ekholm A., 1987, Systemet Människa-Byggnadsverk - Ett ontologiskt perspektiv. Statens råd för byggnadsforskning R22:1987, Stockholm.

Ekholm A. and S. Fridqvist, 2000, “A concept of space for building classification, product modelling, and design”. Automation in Construction, 9(3), p. 315-328.

Ekholm A. and S. Fridqvist, 1998, “A dynamic information system for design applied to the construction context”. In: Björk B.-C. and A. Jägbeck (eds) The Life-Cycle of IT Innovations: Proceedings of the CIB W78 Conference, June 3-5, 1998. Royal Institute of Technology, Stockholm.

Ekholm A. and S. Fridqvist, 1996, “Modelling of user organisations, buildings and spaces for the design process”. In Turk Z. (ed.) Construction on the Information Highway. Proceedings from the CIB W78 Workshop, 10-12 June 1996, Bled, Slovenia.

Fridqvist S. 2000, Property-oriented information systems for design. Prototypes for the BAS·CAAD project. (Diss.) Lund Institute of Technology, Lund University, Lund

ISO 1985, Concepts and terminology for the conceptual schema and the information base ISO/DTR 9007 (TC97), also SIS teknisk rapport 311. SIS, Stockholm.

Palladio, A. 1997, Four books on architecture. Translation by R. Tavernor and R Schofield. MIT Press, Cambridge.

Rittel H. 1984, In N. Cross Developments in Design Methodology. John Wiley and Sons, London.

Simon H. 1981, The Sciences of the Artificial. MIT Press, Cambridge.

Schenck D. A., and P. R. Wilson, 1994, Information modelling: The EXPRESS Way. Oxford University Press, Oxford.

The Swedish Building Centre 1999. BSAB 96 The Swedish construction industry classification system. The Swedish Building Centre, Stockholm.

Webster’s 1979, Webster’s New Collegiate Dictionary. G&C Merriam Co., Springfield, Massachusetts.